

An examination of drag reduction mechanisms in marine animals, with potential
applications to Uninhabited Aerial Vehicles

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INTRODUCTION

Previous engineering research and development has documented the plausibility of applying biomimetic approaches to aerospace engineering (Anders 2000). Past cooperation between the Virginia Institute of Marine Science (VIMS) and the National Aeronautics and Space Administration (NASA) focused on the drag reduction qualities of the microscale dermal denticles of shark skin (Raschi and Musick 1986). This technology has subsequently been applied to submarines and aircraft. The present study aims to identify and document the three-dimensional geometry of additional macroscale morphologies that potentially confer drag reducing hydrodynamic qualities upon marine animals and which could be applied to enhance the range and endurance of Uninhabited Aerial Vehicles (UAVs). Such morphologies have evolved over eons to maximize organismal energetic efficiency by reducing the energetic input required to maintain cruising speeds in the viscous marine environment. These drag reduction qualities are manifested in several groups of active marine animals commonly encountered by ongoing VIMS research programs: namely sharks, bony fishes such as tunas, and sea turtles. Through spatial data acquired by molding and digital imagery analysis of marine specimens provided by VIMS, NASA aims to construct scale models of these features and to test these potential drag reduction morphologies for application to aircraft design. This report addresses the efforts of VIMS and NASA personnel on this project between January and November 2001.

SPECIMENS REQUESTED

In the initial proposal, NASA expressed interest in the following morphological features:

- a.) Lunate tails in pelagic teleosts such as tuna
- b.) Heterocercal tails from sharks, particularly those with pronounced upper caudal lobes
- c.) Hammerhead shark cephalofoils
- d.) Trailing edge serrations in fins in many species
- e.) Fin-body fillets in sharks
- f.) Flexible trailing edges in shark fins
- g.) Precaudal pits in sharks
- h.) Grooved carapace morphology in sea turtles

Following participation in the June VIMS Longline Survey, NASA officials expressed particular interest in sharks and tunas with lunate tails.

DATA COLLECTION:

Samples were collected by VIMS Longline Survey personnel aboard the Research Vessel Bay Eagle for subsequent molding and photography by NASA technicians. Some early success was noted from a night shark specimen molded after being preserved in ethanol by VIMS staff. Attempts in February and March to mold animals and fins that had previously been frozen at VIMS proved unsuccessful. The freezing process deformed fins, particularly the leading and trailing edges, and made it difficult to mold specimens in a natural posture. NASA requested fresh specimens from the VIMS Longline Survey sampling cruises. The June survey, on which 2 NASA representatives accompanied VIMS personnel, produced 7 common coastal shark species, none of which possess lunate fins. A special longline set, aimed at capturing more pelagic animals such as tunas and mako sharks, was made at Norfolk Canyon (approximately 70 miles offshore) during the June survey but yielded no animals of interest. Catch at all stations in all months was dominated by common members of the Family Carcharhinidae- sandbar, dusky, and Atlantic sharpnose sharks. NASA indicated particular interest in sharks and fish with lunate tails, e.g. mako sharks and tunas. The 182 cm tiger shark landed on the August 2001 survey provided the best example to date of a caudal keel. NASA obtained the necessary information from detailed digital photography rather than molding for this specimen.

Description of specimens collected and supplied by VIMS to NASA

2 great white sharks, *Carcharodon carcharias*- frozen from November 2000

1. 202 cm total length- dorsal and caudal fins removed from specimen
2. ~180 cm total length- dorsal, caudal and pectoral fins molded from complete specimen

1 tiger shark, *Galeocerdo cuvier*- August VIMS Longline Survey

182 cm total length- dorsal and caudal fins removed from specimen

1 night shark, *Carcharhinus signatus*- preserved in ethanol

100 cm total length- dorsal and pectoral fins molded from complete specimen

1 bonnethead shark, *Sphyrna tiburo*- preserved

~55 cm total length- cephalofoil molded from complete specimen

1 sandtiger shark, *Carcharias taurus*- June VIMS Longline Survey

275 cm total length- caudal fin removed from specimen

Sandbar sharks, *Carcharhinus plumbeus*- June VIMS Longline Survey

Digital photographs taken by NASA personnel

Dusky sharks, *Carcharhinus obscurus*- June VIMS Longline Survey

Digital photographs taken by NASA personnel

Work sessions by NASA personnel at VIMS

January 2001: Molding of night shark

January 2001: Planning meeting at VIMS to discuss previous results and prospects for the current collaboration:

John A. Musick, Mark R. Patterson, W. Wesley Dowd, and Kenneth Goldman - VIMS.

John B. Anders, Barry S. Lazos, and Robert Bayles - NASA.

February 7, 2001: Peter Vasquez, NASA - Molding of white shark.

February 22, 2001: Peter Vasquez and Barry S. Lazos, NASA- Molding of white shark.

February 27, 2001: Peter Vasquez and Barry S. Lazos, NASA- Molding of white shark.

June 11-13, 2001: Barry S. Lazos and Margaret Hopkins on June longline survey aboard VIMS R/V Bay Eagle.

September 7, 2001: Progress meeting at NASA Langley:

John A. Musick and Mark R. Patterson – VIMS.

John B. Anders and Barry S. Lazos – NASA.

VIMS Longline Survey Sea Time and Catch

June: Six VIMS and two NASA personnel conducted longline surveys aboard the R/V Bay Eagle from June 11 to June 13 and June 18 to June 19. 1486 hooks were set in 14 sets, landing 130 sharks. These included 102 sandbar, 11 Atlantic sharpnose, 9 dusky, 4 spinner, 2 blacktip, 1 sandtiger, and 1 smooth hammerhead sharks. NASA and VIMS personnel attempted to mold the caudal fin of the sandtiger shark aboard the vessel, but sea conditions prevented this mold from being successful.

July: Seven VIMS personnel conducted longline surveys aboard the R/V Bay Eagle from July 9 to July 12. 1440 hooks were set in 14 sets, landing 126 sharks. These included 83 sandbar, 33 Atlantic sharpnose, 6 blacktip, 3 sandtiger, and 1 tiger shark.

August: Seven VIMS personnel conducted longline surveys aboard the R/V Bay Eagle on August 14 and from August 21 to August 23. 1240 hooks were set in 11 sets, landing 126 sharks. These included 118 sandbar, 1 dusky, 1 tiger, and 6 Atlantic sharpnose sharks. Other samples included 3 cobia, 1 barracuda, and 1 spadefish.

September: Seven VIMS personnel conducted longline surveys aboard the R/V Bay Eagle from September 26 to September 27. 1040 hooks were set in 9 sets, landing 71 sharks. These included 57 sandbar, 3 dusky, 8 Atlantic sharpnose, 2 sandtiger, and 1 smooth dogfish.

October: Seven VIMS personnel conducted longline surveys aboard the R/V Bay Eagle from October 9 to October 11. 1260 hooks were set in 10 sets, landing 63 sharks. These included 13 sandbar, 3 dusky, 7 sandtiger, 9 sharpnose, and 31 smooth dogfish.